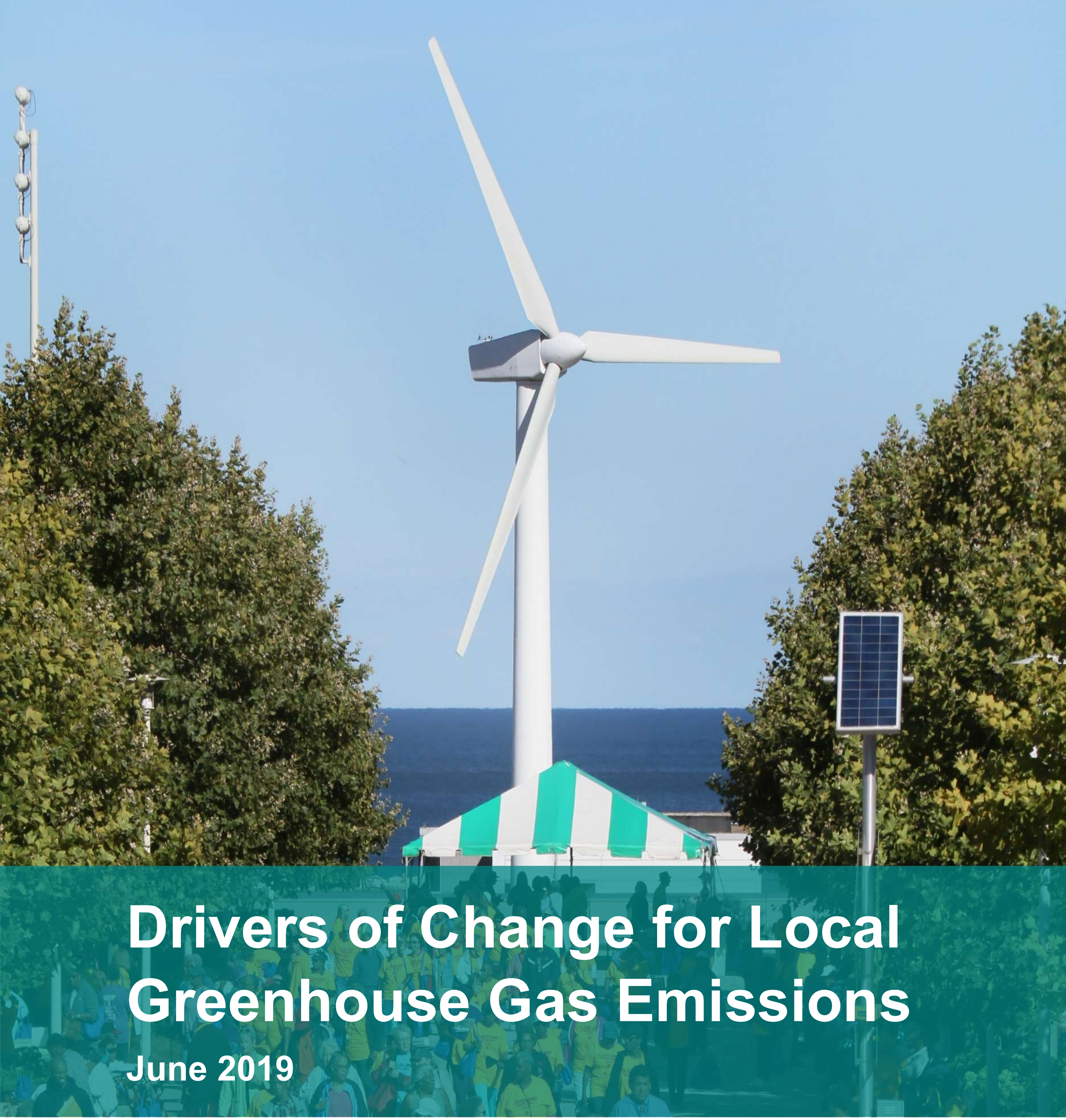

Drivers of Change for Local Greenhouse Gas Emissions

June 2019

City of Bellevue Washington

ICLEI Local Governments for Sustainability USA

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Acknowledgements

Project Team

Jennifer Ewing	Environmental Stewardship Program Manager Bellevue, Washington
Mike Steinhoff	Program Director, Tools and Technical Innovation ICLEI USA-Local Governments for Sustainability
Eli Yewdall	Senior Program Officer ICLEI USA-Local Governments for Sustainability
Hoi-Fei Mok	Program Officer ICLEI USA-Local Governments for Sustainability
Angie Fyfe	Executive Director ICLEI USA-Local Governments for Sustainability
Ookie Ma	Physical Scientist U.S. Department of Energy (DOE)

Steering Committee

Chris Menges Ashley Perl	Aspen, Colorado
Shawn Megill Legendre Robert Graff	Delaware Valley Regional Planning Commission
Rachel Brombaugh Carrie Lee Matt Kuharic	King County, Washington
Maia Davis Timothy Masters Jeffrey King	Metropolitan Washington Council of Governments
Garrett T. Wong	Santa Monica, California
Andrea Martin	Cascadia Consulting, Inc.
Roel Hammerschlag	Hammerschlag & Co.

Pilot Communities

Adam Hanks	Ashland, Oregon
Anand Natarajan Matt Gray Rika Meschkat Becca Stock	Cleveland, Ohio
Thomas Herrod	City and County of Denver, Colorado
Tobin Fried	City and County of Durham, North Carolina
Erik Pearson	Hayward, California
Patricia Gomez Michele Markovits Susannah Troner	Miami-Dade County, Florida
Michelle Hamman	Metropolitan Government of Nashville and Davidson County, Tennessee
Danelle MacEwen	Olympia, Washington
Kyle Diesner	Portland, Oregon
Miranda Redinger	Shoreline, Washington

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Contents

Key Findings

As cities in the United States take action on climate, they use a greenhouse gas (GHG) emissions inventory to track progress and measure the impact of their actions. As GHG emissions inventory methods have evolved, so has a growing need for a deeper understanding of what is driving changes in emissions inventories from year to year. The Analyzing Drivers of Change in Greenhouse Gas Emissions Inventory project pioneered the development of an analytical tool and methodology called the contribution analysis. The contribution analysis methodology was applied to GHG emissions inventories of two different years for 15 different communities to analyze the drivers of change from one inventory year to another.

1. **Both a cleaner electric grid and energy efficiency have important parts to play in offsetting growth and reducing emissions from commercial and residential electricity use.** State-level policies advancing renewable energy, combined with local, utility, business, and individual action for energy efficiency and renewable energy can overcome growth and drive significant emissions reductions.

2. **More-efficient vehicles and reduced vehicle miles per person are key factors in offsetting growth and reducing emissions from on-road transportation.** In most communities analyzed, improvements in vehicle fuel efficiency and reductions in vehicle miles per person were enough to reduce absolute emissions, despite potentially increased transportation use from population growth.

3. **Addressing transportation emissions is more challenging than electricity emissions, and more work is needed.** While the overall trend is in the right direction, transportation emissions are not decreasing as rapidly as those from electricity, and emissions are still increasing for more than a third of communities. More work is needed to address both vehicle miles and vehicle fuel efficiency or fuel switching to cleaner alternatives.

For each inventory pair, emissions from residential and commercial buildings and their associated electricity use and from on-road transportation were analyzed for changes driven by factors such as weather, grid carbon intensity, on-road fuel economy, community growth, and specific actions taken by each community. Overall, the analysis shows that progress is being made to reduce local GHG emissions; however, each city, county, and region has a unique set of factors and challenges related to GHG emissions reduction that should be considered to identify the right mix of mitigation strategies to address the specific local context.

Introduction and Project Description

Introduction

The Intergovernmental Panel on Climate Change (IPCC) indicates that global average temperatures have already risen 1 degree Celsius above preindustrial levels, and the impacts of this warming are visible through sea level rise, extreme heat, droughts, reduced Arctic ice, and other effects. The *2018 IPCC Special Report on Global Warming* also concludes that limiting global temperature increases to no more than 1.5 degrees Celsius is necessary to ensure the best outcomes for people and the planet. [1]

While climate change is a global challenge, its impacts are felt and can be mitigated locally. Greenhouse gases (GHG) are primarily emitted by the combustion of fossil fuels to create energy for buildings, transportation, and industrial processes. The responsibilities of local government related to the construction standards of the built environment, the spatial layout of housing and commercial activities, the provision of waste management services, and so on, create an important opportunity for all types of local governments to advance solutions. Cities and counties have worked since the 1990s to measure and manage GHG emissions resulting from activities in their communities—not only as responses to constituents' desires to help solve a pressing global issue, but also to reap the dividends in associated benefits, such as community livability and reduced energy costs.

While local governments have substantial influence on the GHG emissions of their communities, several external factors work both for and against achievement of GHG emissions reduction goal. Energy use in a community is affected by circumstances like population growth and decline, weather, and economic conditions. The actions of firms and individuals in the community cannot be discounted, and the influence of state and regional policy decisions and market impacts on the carbon intensity of the electric grid and federal performance standards in vehicles and appliances all combine to determine the rate at which progress is made. Regardless, local governments engaging in this work take responsibility for the outcomes; fairly or not, their performance is judged on the result of these interacting factors.

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[1] See *IPCC Special Report on Global Warming of 1.5℃* here: http://www.ipcc.ch/report/sr15/.

GHG inventory protocols were initially developed to provide methodologies to establish a consistent snapshot of the emissions generated by a community for a discrete time period. Only now, with a critical mass of communities performing this task, is it apparent how limited the methods are for understanding changes in GHG emissions over time. As such, the Analyzing Drivers of Change in Greenhouse Gas Emissions Inventories project is necessary to develop a new methodology for understanding these trends and the factors having the greatest influence on driving increases or decreases to an emissions inventory.

Furthermore, understanding program effectiveness is also crucial for local policymakers to double down on effective solutions, pivot away from those with little impact, and share lessons learned with the broader field. But evaluations of each specific action a local government takes are unrealistic, due to costs and the diffuse and incremental nature of actions aimed at transforming the built environment to a more energy efficient and climate-friendly state. This prompted a need to explore new options for evaluating progress at the city-wide scale in a way that dovetails with current GHG inventory practice and can be incorporated into the existing analyses that many communities already undertake. In scoping the initial project idea, the concept of a contribution analysis fits the overall need.[2]

Through a contribution analysis, a community can attribute changes to external drivers by supplementing their inventory data with additional contextual information and, as a result, have a clearer signal of real progress toward improved efficiency. This project establishes a replicable framework that can be used by local governments throughout the country to attribute the observed changes in community GHG emissions inventories over time. Practitioners can now harness data to produce a more accurate depiction of changes to community-scale inventories, communicate those trends more clearly, and use the data to evaluate the effectiveness of policies and programs.

Project Description

The need to better understand trends in GHG emissions inspired the application to the Cities Leading through Energy Analysis and Planning (Cities-LEAP) project to develop methods and an off-the-shelf toolkit designed to allow practitioners to immediately

[2] Better Evaluation. “Contribution Analysis.” Accessed December 2018. https://www.betterevaluation.org/en/plan/approach/contribution_analysis.

incorporate the results of this work into their own local climate change mitigation programs.[3] The City of Bellevue, Washington partnered with ICLEI USA—which has a long history of collaborating with the communities in its member network—to design the project and recruit additional practitioners to form a project steering committee to both test the applicability and relevance of the methods to their work to ensure a valuable end product. The deliverable produced for this project is a toolkit consisting of spreadsheet tools to perform analyses, guidebooks, and several other training materials that support users in performing their own contribution analyses.

Because this project was developed in collaboration with 16 communities, it provided an opportunity to interpret the results of each together and also make some general observations about how internal and external factors contribute to any community reaching for deep reductions in the GHGs attributable to its municipal operations, residents, and business community. These findings have already made a mark on the dialogue for subnational GHG accounting and have been cited in the relevant chapter of the *2018 Emissions Gap Report* by U.N. Environment.[4] This report includes a summary of findings, the process of developing the toolkit, and implications for continuing related work in this area.

The goal of this project was to develop and test new methodologies for performing a contribution analysis of community-scale GHG emissions and create an off-the-shelf toolkit to support widespread dissemination of the results. The following sections summarize the activities taken to develop and publish the toolkit.

Inventory Data Conditioning

The team initially anticipated that significant data conditioning and updating might be needed to work with the methodology. In part due to the advanced state of practice among the Steering Committee communities, relatively little work needed to occur in this case. All Steering Committee communities obtained a sample of monthly utility data needed to perform a regression analysis and account for the impacts of weather, which was an unexpected outcome. Again, this may be due to the relatively close relationships with Steering Committee members and their energy utilities as a result of long-standing investments in GHG inventory work.

Contribution Analysis Model Development

[3] EERE (Office of Energy Efficiency & Renewable Energy). “Cities Leading Through Energy Analysis and Planning.” https://www.energy.gov/eere/cities-leading-through-energy-analysis-and-planning.
[4] UNEP (U.N. Environment Program). *Emissions Gap Report 2018*. Nairobi, Kenya: 32.

The first step in model development consisted of an initial literature review for related methodologies to plan the overall form and function of the toolkit. The model development team began by looking outside the energy and emissions accounting fields for examples addressing the same fundamental question applied to different subjects (e.g., combinations of factors contributing to the price of goods or commodities). With little success, the search eventually returned to literature on energy and emissions topics, where the team found the Logarithmic Mean Divisia Index (LMDI) method used for similar types of analyses.[5,6]

As the model was iteratively developed and tested with the project Steering Committee communities, data request specifications to enable jurisdictions to request required data from local and regional entities were created from the experiences in gathering and conditioning data in each circumstance. A key specification was developed for building energy use, which enabled the contribution analysis to perform heating and cooling degree-day normalization. These specifications were ultimately refined for the final toolkit distribution file.

The team sought to leverage and integrate other federal data sources throughout the project, attempting to scale coefficients from the EIA Short-Term Energy Outlook model for the local level.[7] The intention was for these data to serve as a fallback for heating- and cooling-degree days normalization for jurisdictions that lacked adequate utility data. Equations from the EIA Short Term Energy Outlook model also served as useful starting points for predicting the impact of weather and economic variables on energy and fuel usage.

The team determined parameters from the EIA Short Term Energy Outlook model would not work well as part of a local contribution analysis. The effects of variations in climate, building stock, and commercial building end uses were too great for the national parameters to be useful.

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[5] Marcucci, Adriana, and Panagiotis Fragkos. "Drivers of Regional Decarbonization through 2100: A Multi-model Decomposition Analysis." *Energy Economics* 51 (September 2015): 111-124. https://doi.org/10.1016/j.eneco.2015.06.009.

[6] Belzer, D.B. *A Comprehensive System of Energy Intensity Indicators for the US: Methods, Data and Key Trends*. Pacific Northwest National Lab, August 2014. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22267.pdf.

[7] U.S. Energy Information Administration. "Short-Term Energy Outlook." Last modified June 11, 2019. https://www.eia.gov/outlooks/steo/.

Note that two sources originally mentioned in Statement of Project Objectives were not deemed useful in this effort. The EIA Manufacturing Energy Consumption Survey[8] (MECS) dataset proved challenging to apply, due to the inability to appropriately match energy consumption identified by utilities as industrial to the specific North American Industry Classification System (NAICS) business codes needed to predict the expected energy intensity of a given community industrial sector. This is further complicated by the scale of available economic data of industries by NAICS codes, which cannot be reliably downscaled to an individual city the way that more uniform commercial activity can be.

Contribution Analysis of Participating Communities

After the theoretical approach to the toolkit was finalized and successfully demonstrated, the project team applied it to the Steering Committee members' data first. As the project was moving quickly and under budget, the decision was made to expand the testing period to gain wider use from a few additional communities. The results of these pilot tests are included in the following section on Steering Committee and Pilots Summary Results. The team experienced no significant setbacks, supporting the conclusion that the tool was ready for publication and distribution.

Completed Contribution Analysis Toolkit

Preparation for public launch included refining the spreadsheet for easy navigation and data entry. Several supplementary training and support materials were also created, including the following resources:

- A full user guide detailing the technical background needed to understand methodologies and inner workings of the spreadsheet;
- A quick start guide for users who simply need instruction on using the tool; and
- 11 online interactive training modules.

The toolkit was made available for download from the ICLEI-USA website on July 18, 2018. In the six months from that date to the end of the grant period, the toolkit was downloaded 234 times by a diverse audience throughout the United States and internationally.

U.S. Community Protocol Updates

The process of developing and testing the toolkit revealed several new best practices in GHG inventory development that support this type of analysis. To ensure those

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[8] U.S. Energy Information Administration. "Manufacturing Energy Consumption Survey (MECS)." Last modified September 6, 2018. https://www.eia.gov/consumption/manufacturing/.

practitioners creating baseline inventories are anticipating these needs, updates to the U.S. Community Protocol were developed to inform decision-making on sources of inventory data and documentation of the inventory and related context data. [9]

[9] ICLEI (Local Governments for Sustainability). "Greenhouse Gas Protocols." Last modified 2019. http://icleiusa.org/ghg-protocols/.

Steering Committee and Pilots Summary Results

What Has Been Driving Emissions?

As the toolkit was developed, the methods were tested with the inventory data of 16 different jurisdictions across the United States from the project Steering Committee and other participating communities (see Figure 1). The following sections summarize the findings from each of those pilot tests. While some trends are evident across communities, it is worth noting the findings are as diverse as the communities themselves.

- Population
- Commercial sector size
- Weather
- Household energy use intensity
- Commercial use intensity
- Vehicle fuel economy
- Vehicle miles traveled per capita
- Electric fuel mix
- Waste per capita
- Industrial emissions

Pilot Communities

Participating Steering Committee Cities

- Aspen, CO
- Bellevue, WA
- Delaware Valley Regional Planning Commission
- King County, WA
- Metro Washington Council of Governments
- Santa Monica, CA

Second Round Participating Cities

- Ashland, OR
- Cleveland, OH
- City and County of Denver, CO
- Durham City and Durham County, NC
- Hayward, CA
- Miami-Dade County, FL
- Metro Government of Nashville & Davidson County, TN
- Olympia, WA
- Portland, OR
- Shoreline, WA

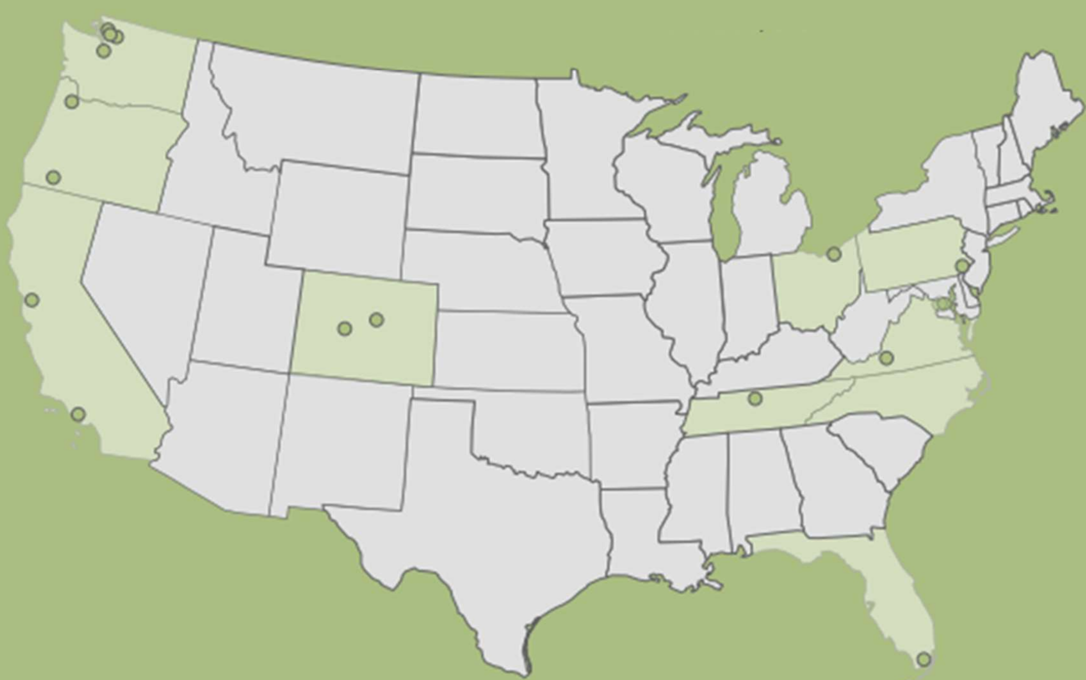


Figure 1. Map and list of steering committee and pilot communities

Aspen, Colorado

The City of Aspen conducted its first GHG inventory in 2004 and started its planning process not with a focus on climate mitigation, but on adaptation, releasing its first climate impact report in 2006, showing potential end of skiing by 2100. Aspen's work to mitigate emissions began in earnest in 2007 under its Canary Initiative. Aspen will use the contribution analysis to continually refine its climate mitigation strategies.

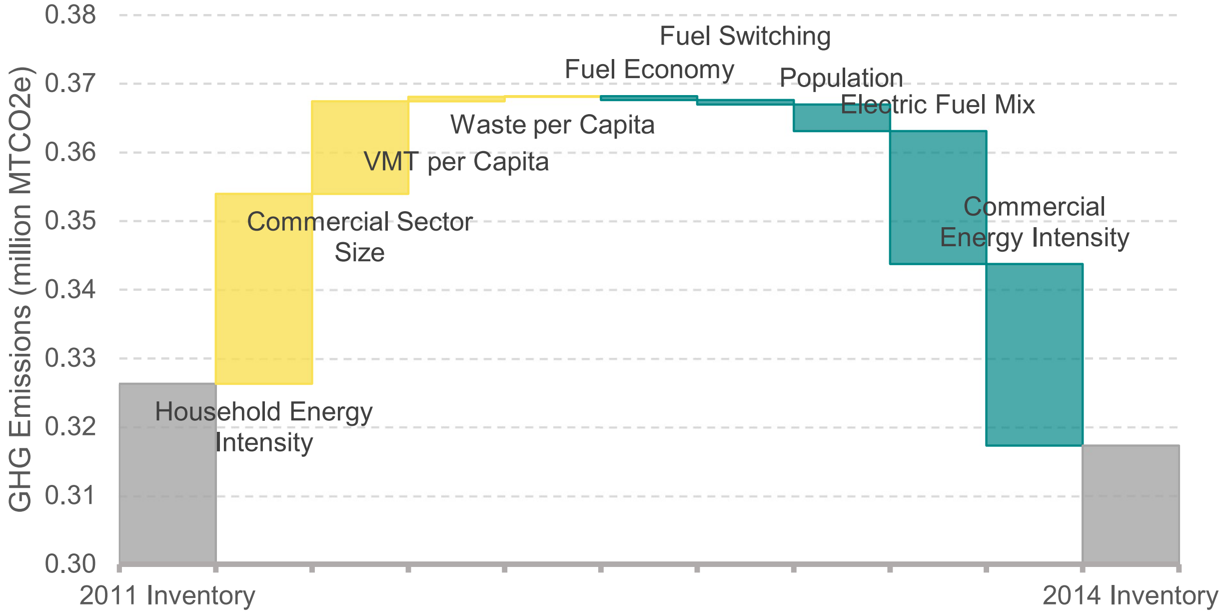
The City of Aspen conducted an analysis of its past community GHG emission trends for 2011-2014. While Aspen experienced increased residential energy usage per household and job growth, overall emissions reductions were achieved through decreased commercial energy usage per job, a cleaner electrical grid, and a warmer winter. Over the past 30 years, the number of snow days per year in Aspen decreased by 23 days.

Largest Contributors to Emissions Growth

- Increased household energy intensity
- Increased commercial sector size

Largest Contributors to Emissions Decline

- Reduced commercial energy intensity
- Less carbon-intensive electric fuel mix



Bellevue, Washington

The Bellevue community values services and infrastructure that reliably ensure public health and safety, as well as protect the environment; stewardship and education that sustain a healthy environment for current and future generations; a healthy natural environment that supports wildlife; and a nature experience in which to live, work, learn, and play. Using seven measures to evaluate performance, Bellevue's approach to climate action takes a holistic community view.

What is Driving the Trends

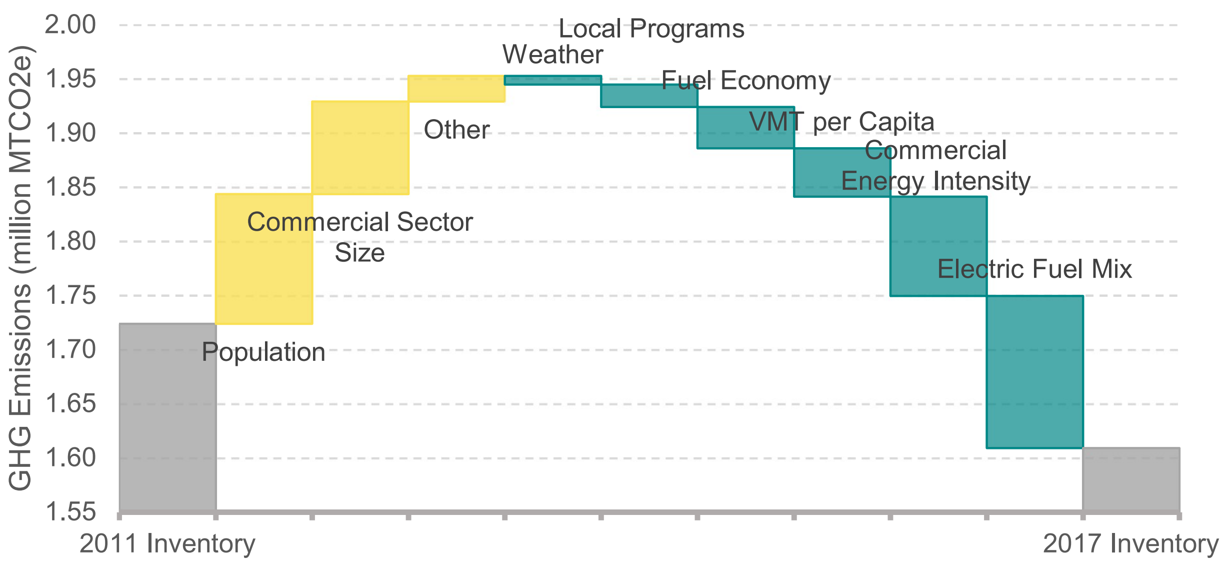
The City of Bellevue conducted an analysis of its past community GHG emission trends for 2011-2017. The results show Bellevue and its surrounding region are experiencing emissions increases attributable to job and population growth; however, a much cleaner electricity grid and local initiatives (i.e., transit-oriented development resulting in reductions in driving per person and increased energy efficiency in commercial buildings) are outpacing growth-related increases.

Largest Contributors to Emissions Growth

- Population growth
- Increased commercial sector size

Largest Contributors to Emissions Decline

- Less carbon-intensive electric fuel mix
- Reduced commercial energy intensity



Delaware Valley Regional Planning Commission

Delaware Valley Regional Planning Commission (DVRPC) is the federally designated Metropolitan Planning Organization for a diverse nine county region of the greater Philadelphia area, spanning Pennsylvania and New Jersey. DVRPC's vision is a prosperous, innovative, equitable, resilient, and sustainable region that increases mobility choices by investing in a safe and modern transportation system; protects and preserves our natural resources while creating healthy communities; and fosters greater opportunities for all.

What is Driving the Trends

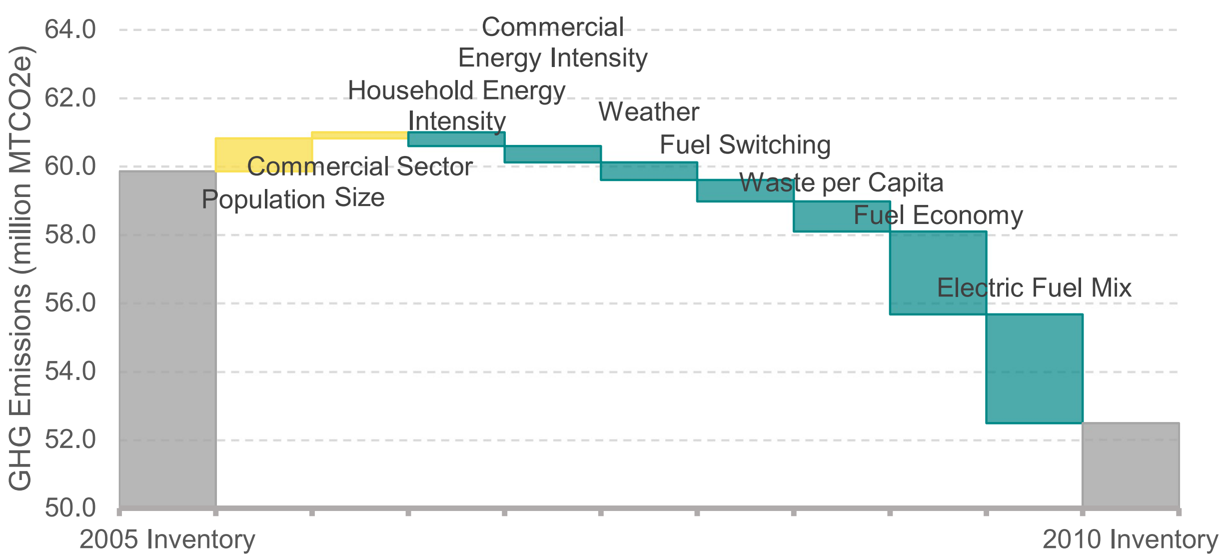
The DVRPC conducted a regional analysis of community GHG emission trends for 2010-2015. The results show the greater Philadelphia region is experiencing slight increases in emissions related to job and population growth; however, greater renewable energy and decreased on-road emissions per mile have helped reduce overall emissions and significantly outpace impacts related to regional growth.

Largest Contributors to Emissions Growth

- Population growth
- Increased commercial sector size

Largest Contributors to Emissions Decline

- Less carbon-intensive electric fuel mix
- Improved vehicle fuel economy



King County, Washington

The 2015 update to the King County Strategic Climate Action Plan integrates climate change into all areas of county operations and community services. The plan is developed through an equity lens and relies on strong partnerships with businesses, residents, and community organizations that represent the diversity of the community. King County seeks to achieve ambitious emissions reduction targets, prepare for climate impacts, and continue to lead on climate action.

What is Driving the Trends

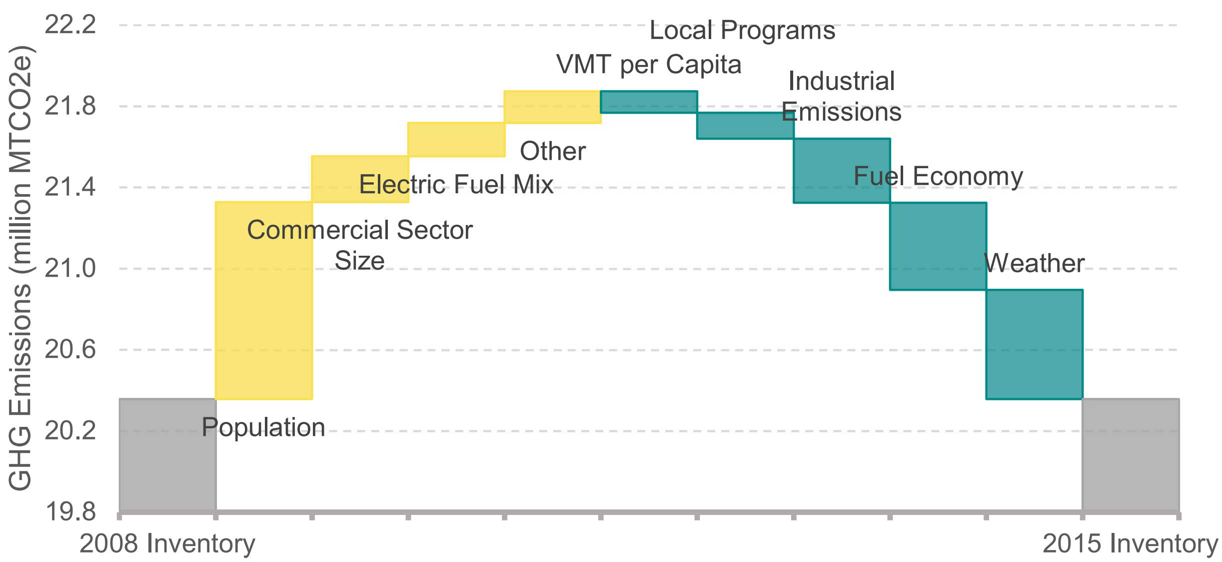
Climate impacts played a role in emissions increases and decreases when comparing 2008 to 2015. In 2015, King County experienced a reduction in hydropower electricity use due to a warmer, drier winter. Population growth and increased commercial floor space also resulted in slight increases. Conversely, the warmer winter reduced heating fuel emissions. Coupled with emissions reductions from non-hydro renewables and improved vehicle fuel economy, King County achieved an overall reduction.

Largest Contributors to Emissions Growth

- ↑ Population growth
- ↑ Increased commercial sector size

Largest Contributors to Emissions Decline

- ↓ Warm winter and cooler summer
- ↓ Improved vehicle fuel economy



Metro Washington Council of Governments

The Metropolitan Washington Council of Governments (COG) is an independent nonprofit association that brings area leaders together to address major regional issues in Washington, D.C., suburban Maryland, and Northern Virginia. In 2008, the COG Board adopted the following regional GHG emission reduction goals : 10% below business-as-usual projections by 2012 (back down to 2005 levels); 20% below 2005 levels by 2020; and 80% below 2005 levels by 2050. COG and its member jurisdictions are working toward these goals.

What is Driving the Trends

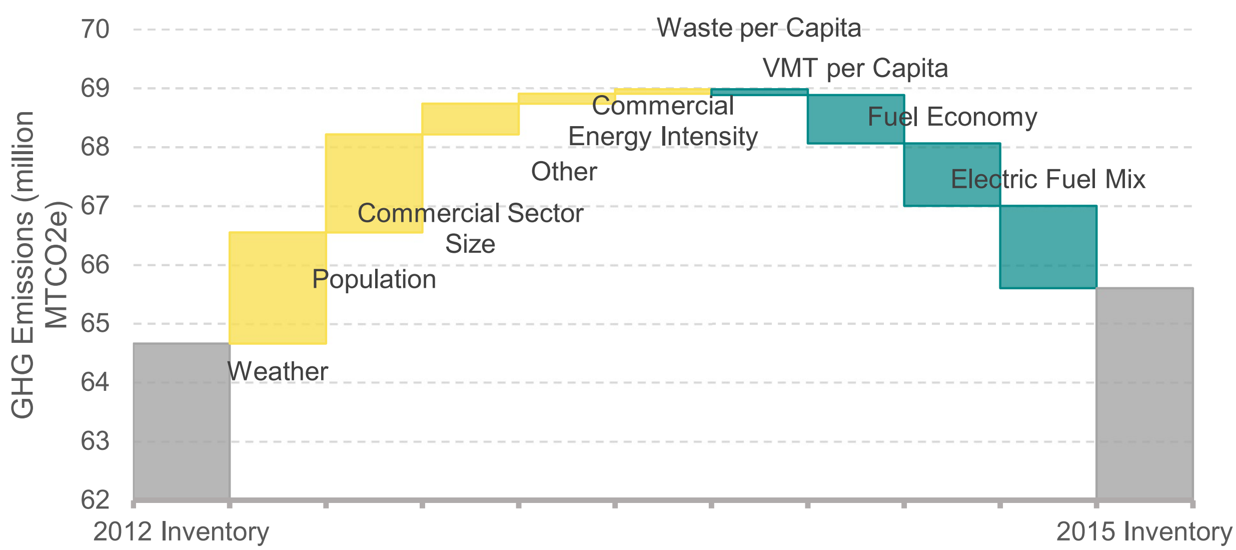
Overall, metropolitan Washington, D.C. GHG emissions decreased 10% between 2005 and 2015; however, there was a slight uptick in emissions for 2012-2015. Therefore, COG applied the contribution analysis to understand what is driving that change. The results show that the colder winter in 2015 and population and commercial growth are the largest contributors to increases, overriding reductions from a cleaner grid, more efficient vehicles, and less driving per capita.

Largest Contributors to Emissions Growth

- Colder winter and warmer summer
- Population growth

Largest Contributors to Emissions Decline

- Improved vehicle fuel economy
- Reduced vehicle miles traveled per person



Santa Monica, California

Santa Monica emerged as an early leader in city sustainability in the 1990s. The Sustainable Santa Monica Plan, first adopted 25 years ago, uses "the power of community to enhance Santa Monica resources, prevent harm to the natural environment and human health, and benefit the social and economic well-being of the community for the sake of current and future generations." The Plan is the bedrock of Santa Monica's climate action.

What is Driving the Trends

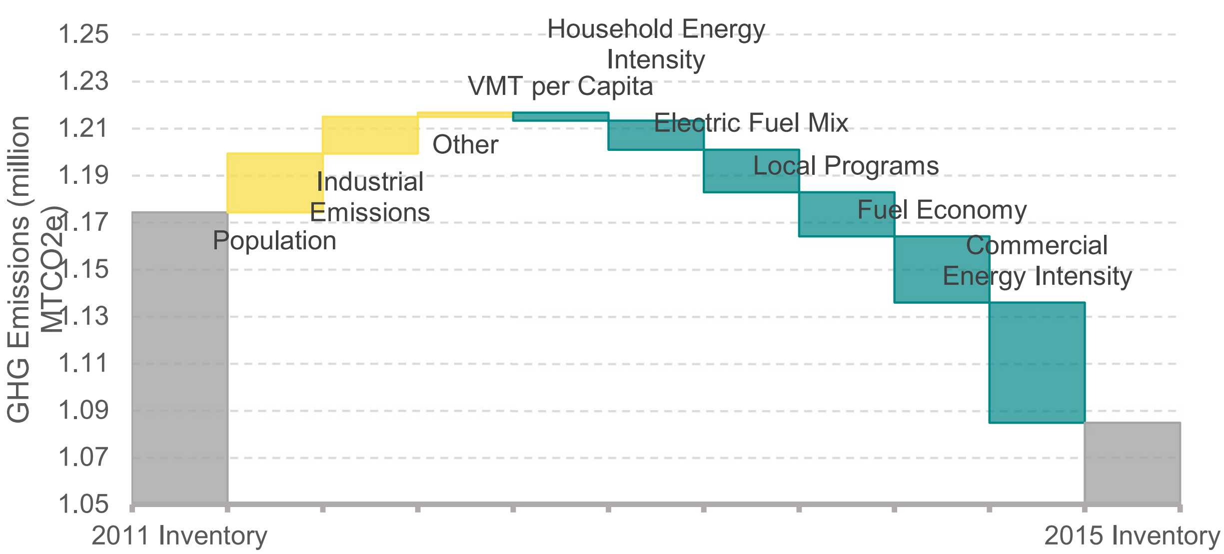
Santa Monica used the contribution analysis to identify drivers of the city's GHG emission trends for 2011-2015. Despite population growth and a warmer summer, overall emissions were reduced through initiatives, such as improved vehicle fuel economy, reduced commercial natural gas and electricity usage, and a cleaner electricity grid. Santa Monica was one of the few pilot cities to achieve larger reductions in building energy use than in the electricity grid.

Largest Contributors to Emissions Growth

- Population growth
- Industrial emissions

Largest Contributors to Emissions Decline

- Commercial energy intensity
- Improved vehicle fuel economy



Ashland, Oregon

The City of Ashland adopted its recent Climate Action Plan in March 2017. Like many western U.S. communities, Ashland expects to see a significant decrease in snowpack and increase in cooling-degree days. In addition to the IPCC sectors considered in the U.S. Community Protocol for GHG Accounting and Reporting, Ashland's inventory also includes residential consumption of goods and food, which is more than a third of Ashland's 2017 consumption-based GHG inventory.

What is Driving the Trends

Ashland ran the contribution analysis on the city's GHG emission trends for 2011-2015. While residential natural gas usage per household and population growth both increased, overall emissions reductions were achieved through a cleaner electricity fuel mix. A warmer winter also contributed to the emissions decrease in 2015.

Largest Contributors to Emissions Growth

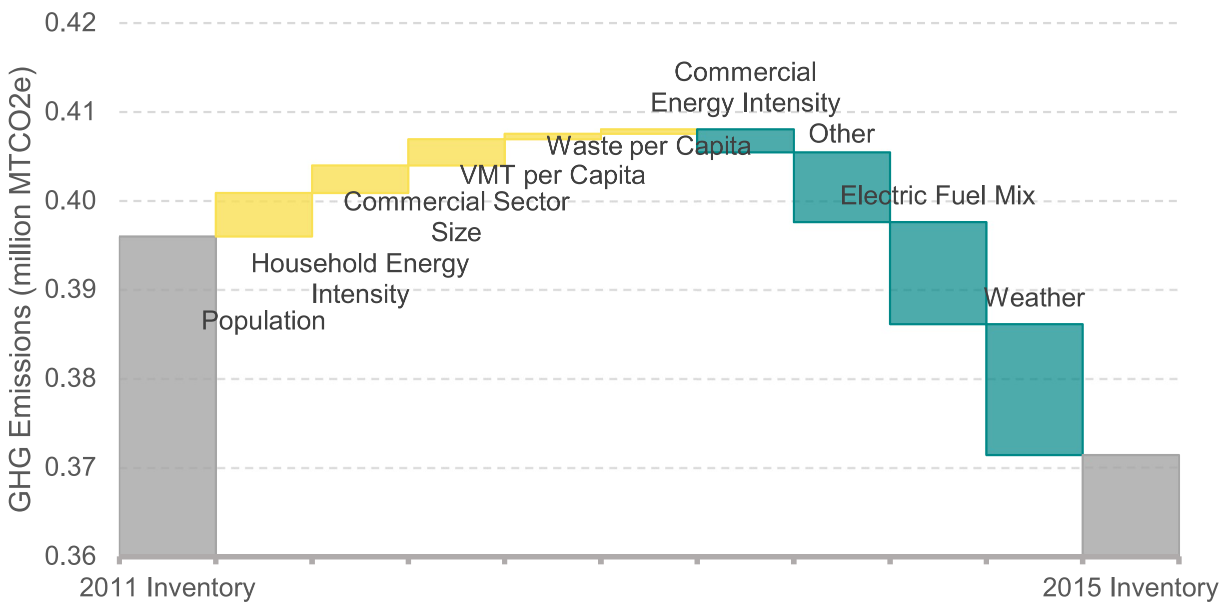
↑ Household energy intensity

↑ Population growth

Largest Contributors to Emissions Decline

↓ Warm winter and cooler summer

↓ Less carbon-intensive electric fuel mix

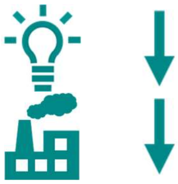


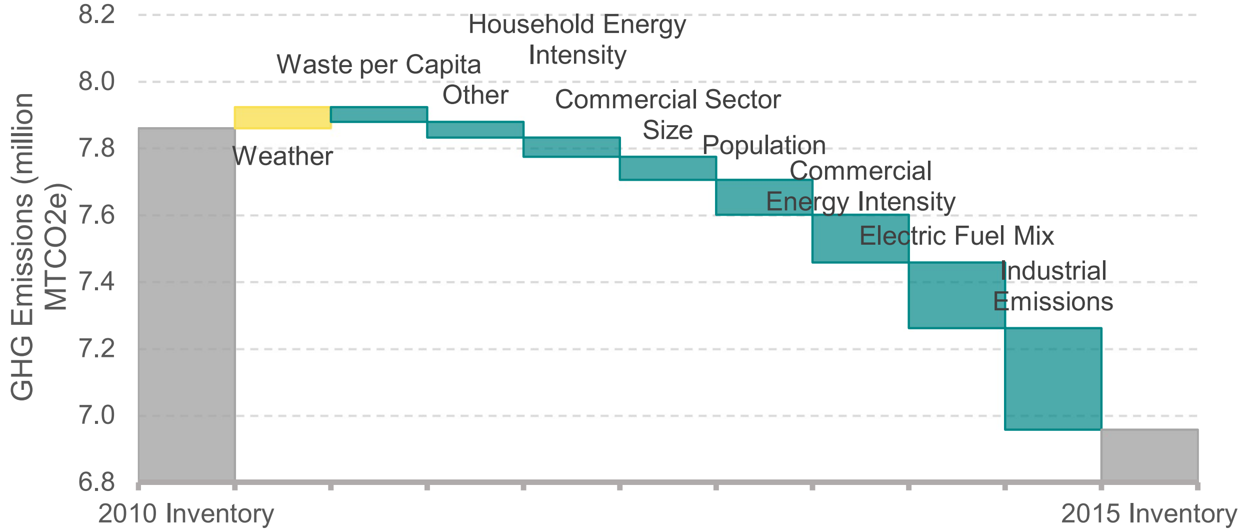
Cleveland, Ohio

Cleveland has a long and effective tradition of climate action. Sustainable Cleveland embraces principles of racial equity, workforce development, climate and social vulnerability assessments, and corporate environmental and social governance. The Cleveland Climate Action Fund supported more than 50 resident-led projects in 2018. More information is available at https://www.sustainablecleveland.org/.

What is Driving the Trends

Cleveland used the contribution analysis to review the city's GHG emission trends for 2010-2015. Cleveland's significant reduction in emissions during this period was hampered only by a colder winter, resulting in increased commercial and residential electricity usage. Overall emissions reductions were observed through decreased commercial natural gas usage and a cleaner electricity fuel mix. Industrial process emissions were not included in the analysis, but the industrial sector has grown, while also becoming more efficient.

Largest Contributors to Emissions Growth	**Largest Contributors to Emissions Decline**
Weather	 Less carbon-intensive electric fuel mix; Reduced industrial emissions



Denver, Colorado

Denver is on track to meet its 2020 climate goal, in part through a strong state renewable energy standard and high-impact policies, such as the commercial building benchmarking and transparency ordinance and the green building ordinance. The benchmarking ordinance, which passed in 2016, achieved a compliance rate of over 90% in its first year. Energy use was cut 4.5% by the 1,161 buildings that reported in both 2016 and 2017. Those owners and tenants saved a collective $13.5 million in 2017.

What is Driving the Trends

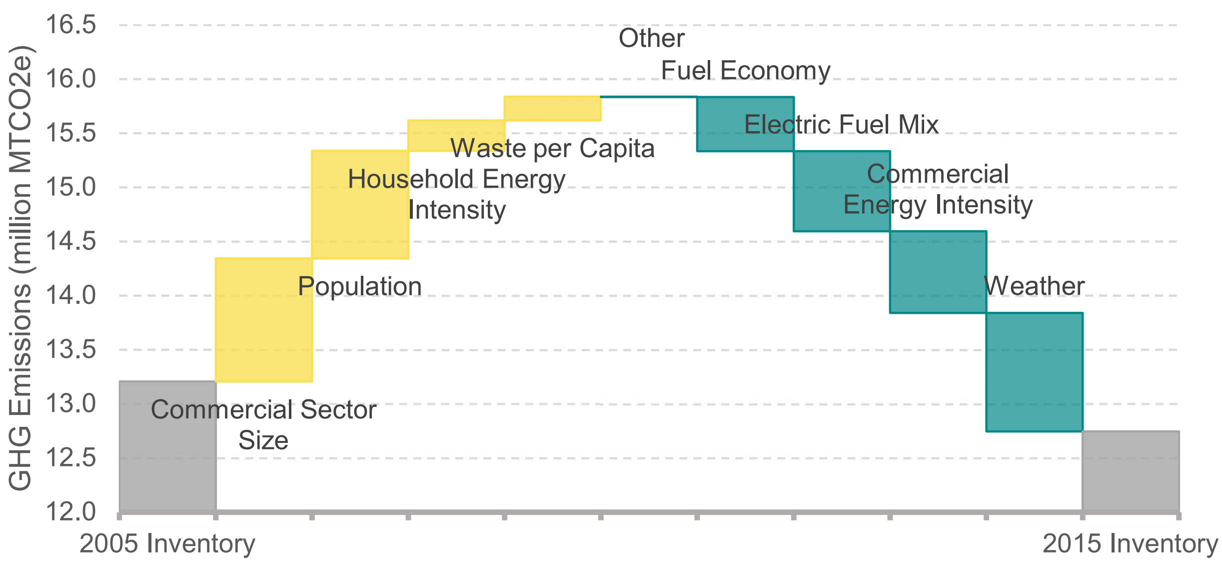
Denver took one of the longer views in its evaluation of the drivers of change, applying the contribution analysis to the city's GHG emission trends for 2005-2015. Growth in population and employment were primary drivers in emissions increases, but these were mitigated by a warmer winter, a cleaner electricity fuel mix, and decreased commercial electricity consumption.

Largest Contributors to Emissions Growth

- Increased commercial sector size
- Population

Largest Contributors to Emissions Decline

- Warmer winter and cooler summer
- Reduced commercial energy intensity



Durham, North Carolina

In November 2018, the City of Durham and Durham County shared a sustainability office and climate action plan. The Durham Board of County Commissioners passed a resolution supporting a transition to renewable energy and the creation of green jobs. In 2007, Durham City and County became the first North Carolina local governments to adopt a GHG emissions reduction target and plan to achieve that goal.

What is Driving the Trends

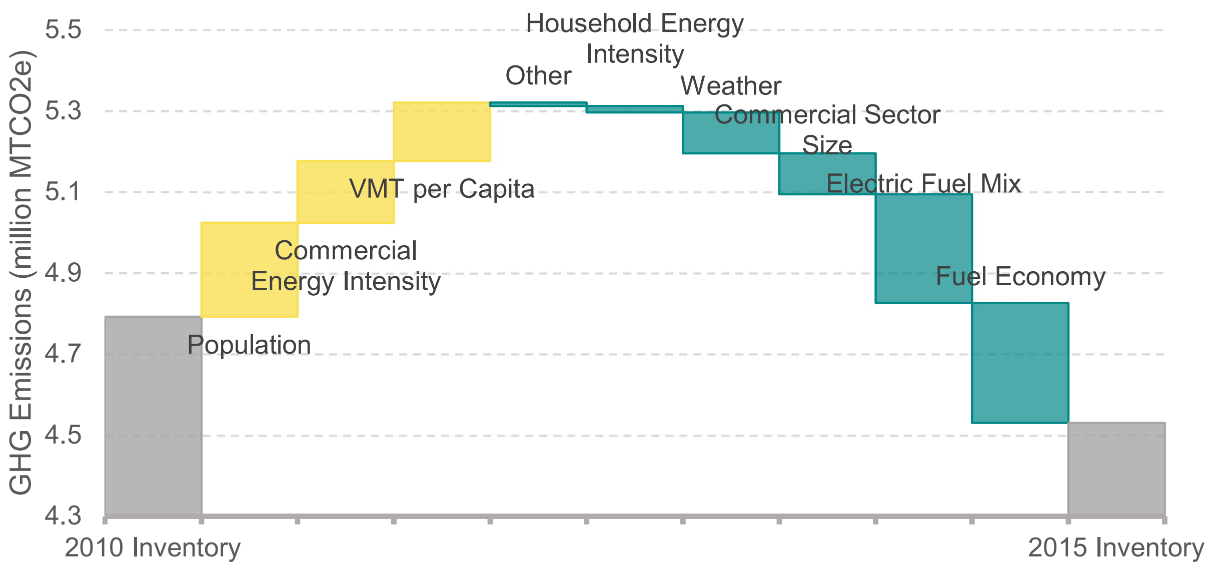
Durham's contribution analysis reviewed the city's GHG emission trends for 2010-2015. Durham made good progress during this five-year period. Population growth increased per capita driving, and increased commercial electricity usage drove emissions upward, but the overall emissions reductions were achieved through decreased on-road emissions per mile, a cleaner electricity fuel mix, and decreased commercial floor area.

Largest Contributors to Emissions Growth

- ↑ Population growth
- ↑ Increased commercial energy intensity

Largest Contributors to Emissions Decline

- ↓ Improved vehicle fuel economy
- ↓ Less carbon-intensive electric fuel mix



Hayward, California

The City of Hayward's initial Climate Action Plan, adopted in 2009, was incorporated into the General Plan in 2014. Hayward's Plan sets a GHG reduction goal of 82.5% from 2005 levels by 2050 and incorporates equity and adaptation measures. ICLEI and the City of Hayward partnered on a youth engagement program—Unite2Green in the frontline neighborhood of Jackson—and this program created youth stewards who delivered energy, water, and waste reduction education in the community.

What is Driving the Trends

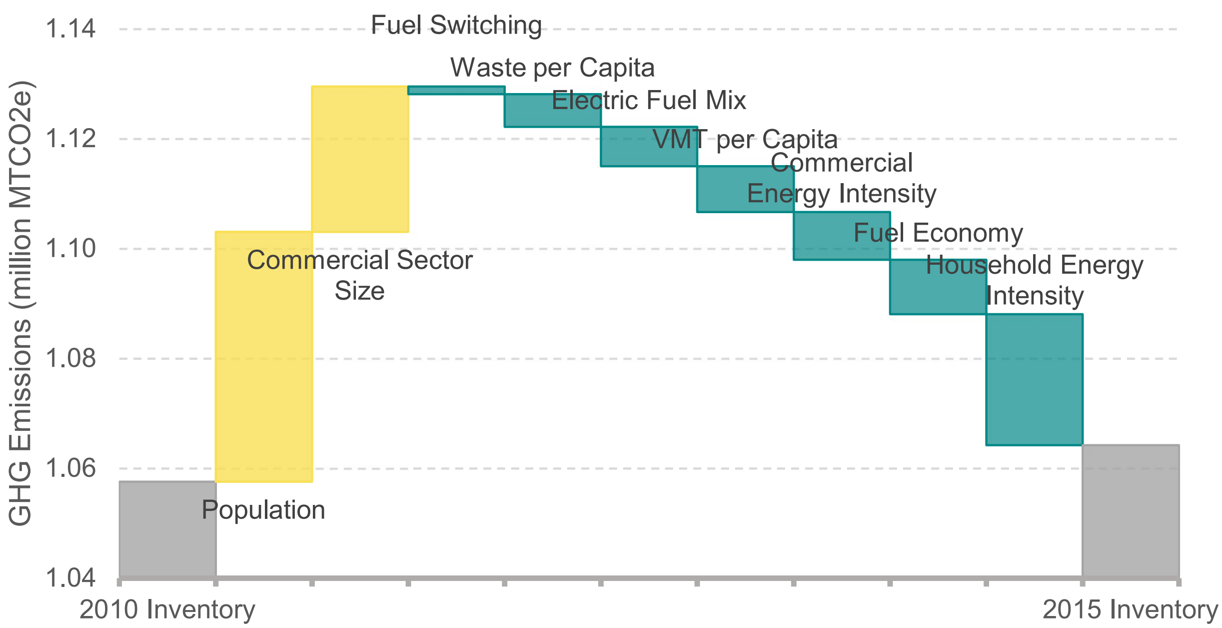
Hayward conducted the contribution analysis on the city's GHG emission trends for 2010-2015. Although there were reductions through decreased residential natural gas usage per household, reduced on-road emissions per mile, and less carbon-intensive electricity, emissions increased overall, largely driven by significant growth in population and employment.

Largest Contributors to Emissions Growth

- Population growth
- Increased commercial sector size

Largest Contributors to Emissions Decline

- Household energy intensity
- Improved vehicle fuel economy



Miami-Dade County, Florida

Florida has one of the highest rates of worker hospitalizations due to heat, exacerbated by climate change, according to *Unworkable*, a report from Public Citizen and the Farmworker Association of Florida. Miami's citizens approved a $400 million bond issue to implement resilience projects and is in tandem working diligently on climate change mitigation activities. The county's actions include 49 policies and resolutions dating back to 1991, when Miami Dade was an early participant in ICLEI's Cities for Climate Protection Program.

What is Driving the Trends

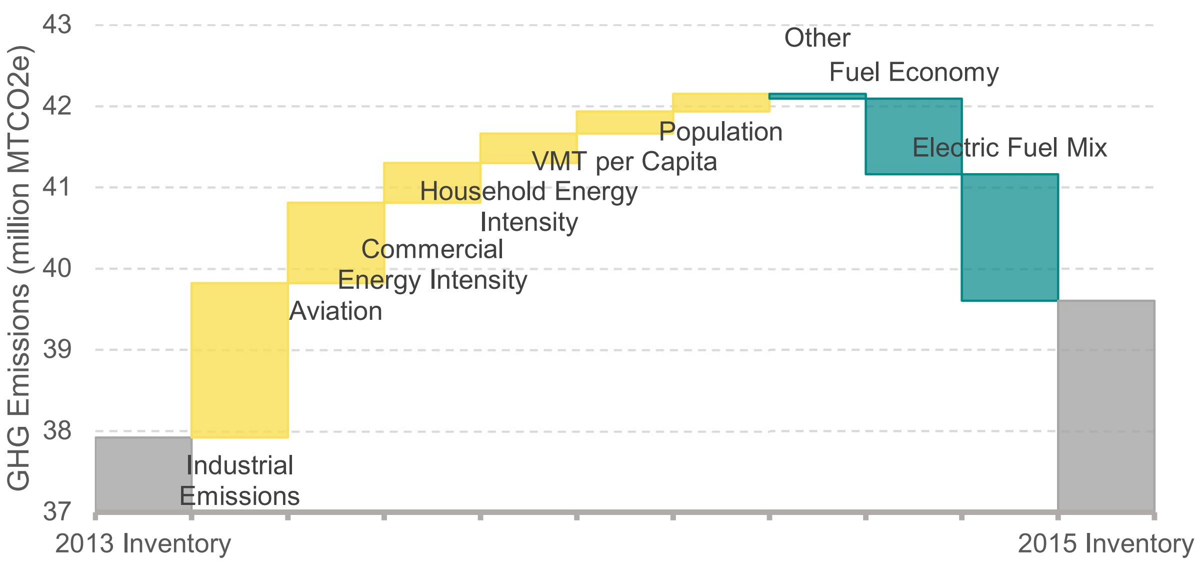
The Miami-Dade County contribution analysis reviewed GHG emission trends over just a two-year period, 2013-2015. Although emissions reductions were achieved through a cleaner electricity fuel mix and decreased on-road emissions per mile, overall emissions went up due to increases in industrial energy emissions, aviation, and residential electricity usage per household. Higher temperatures are increasing energy demand and related emissions in Florida.

Largest Contributors to Emissions Growth

- Industrial energy use
- Aviation energy use

Largest Contributors to Emissions Decline

- Less carbon-intensive electric fuel mix
- Improved vehicle fuel economy



Nashville, Tennessee

Nashville's most recent GHG inventory was updated as part of the City's commitment to the Global Covenant of Mayors for Climate and Energy. The inventory, housed in ICLEI's ClearPath emissions management software, allows the City to transparently and easily share its data with other cities and compare its progress to peer cities. In addition to consideration of renewable energy, energy use, and mobility, the Livable Nashville plan also considers nature-based solutions to create a sustainable community.

What is Driving the Trends

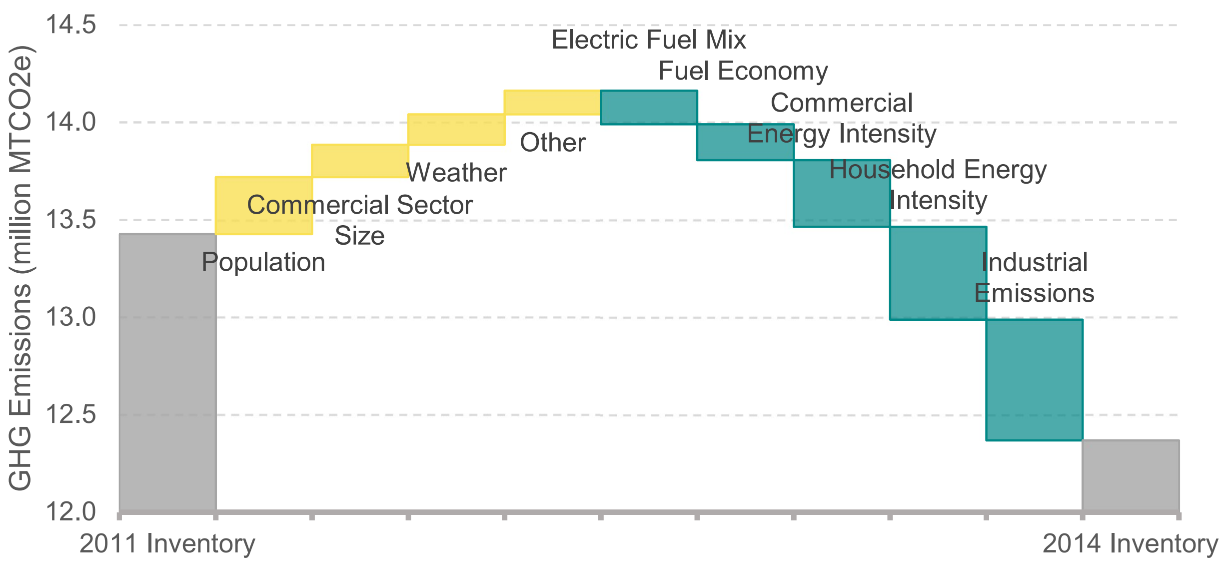
Nashville ran the contribution analysis on the city's GHG emission trends for 2011-2014. While population growth, employment growth, and a colder winter contributed to emissions increases; overall emissions reductions were achieved through decreased industrial energy emissions, residential energy usage per household, and commercial energy usage per job. Tennessee has no requirement for utilities to transition to renewable energy, yet there was an improvement in Nashville's electric fuel mix.

Largest Contributors to Emissions Growth

- Population growth
- Increased commercial sector size

Largest Contributors to Emissions Decline

- Reduced industrial emissions
- Reduced household energy intensity



Olympia, Washington

GHG emissions are one of the key community indicators publicly reported via Olympia's dashboard. The Port of Olympia also conducts an inventory and reports its GHG emissions, and together the city and port have developed a vulnerability study and adaptation plan to prepare for the most likely scenario of 36 inches of sea level rise in Olympia by end of century.

What is Driving the Trends

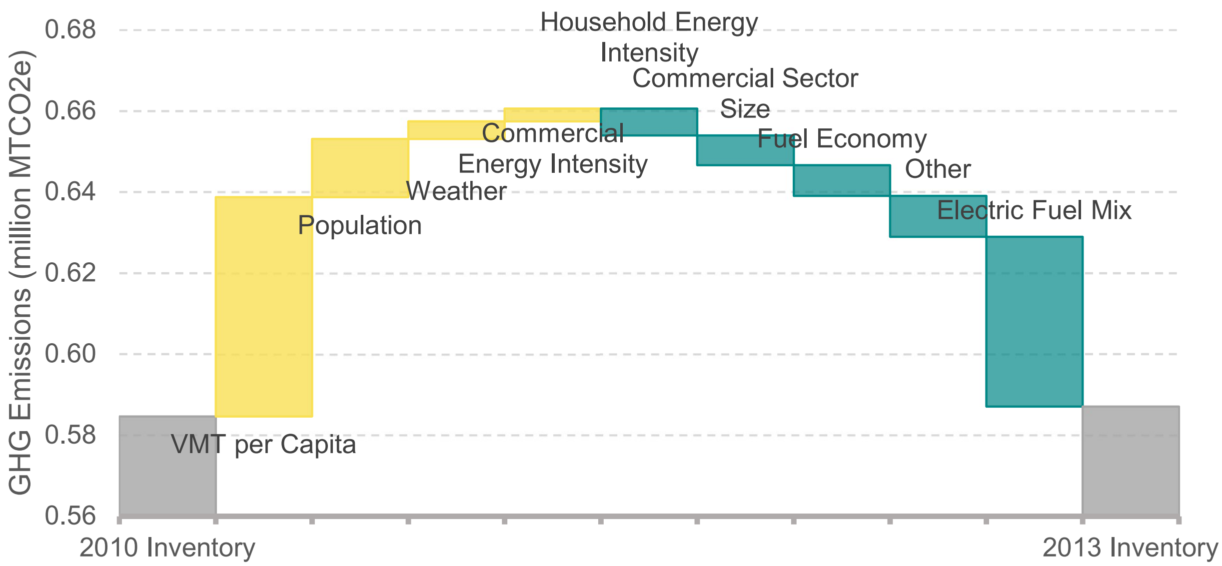
Olympia ran the contribution analysis on the city's GHG emission trends for 2010-2013. A cleaner electricity fuel mix and decreased on-road emissions per mile contributed to emissions reductions, but these achievements were outpaced by emissions from increased per capita driving and growth in population. This trend is similar to what many U.S. cities are experiencing—transportation-related emissions that are more difficult to mitigate than building-related emissions.

Largest Contributors to Emissions Growth

- Increased vehicle miles traveled per capita
- Population growth

Largest Contributors to Emissions Decline

- Less carbon-intensive electric fuel mix
- Improved vehicle fuel economy



Portland, Oregon

The City of Portland is known around the world for its deep commitment to addressing climate change. In 1993, Portland was the first U.S. city to set a carbon reduction target. In addition to its current target to reduce emissions by 80% from 1990 levels by 2050, Portland was one of the first cities in the country to develop an equity-based Climate Action Plan.

What is Driving the Trends

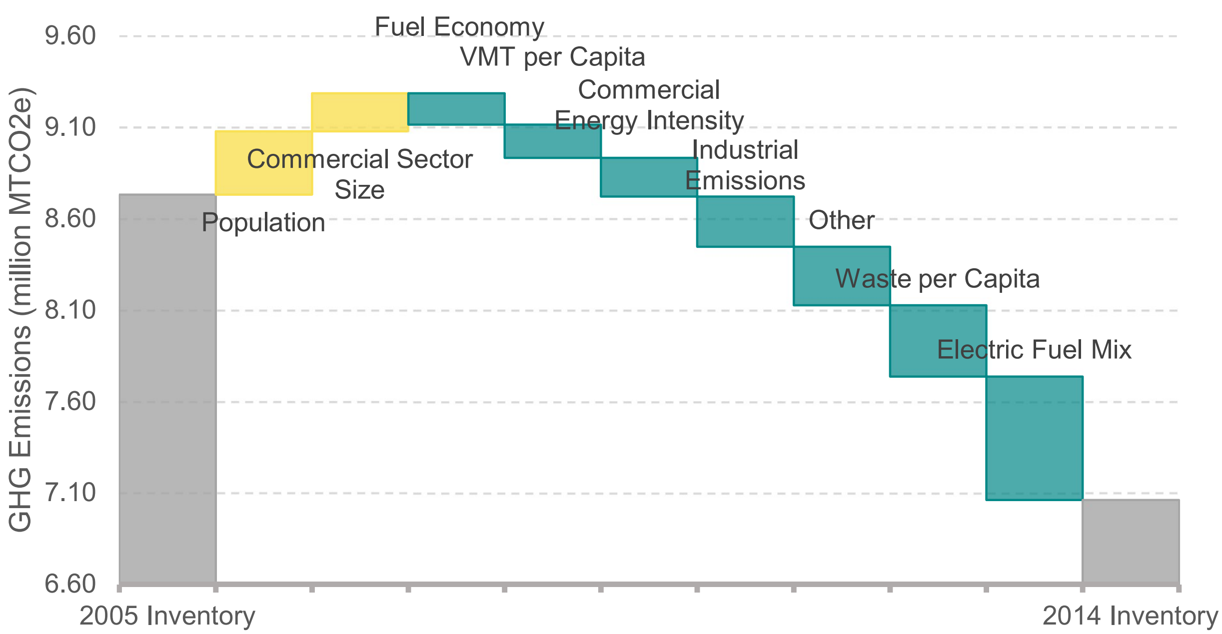
Portland's contribution analysis of the city's GHG emission trends for 2005-2014 considered one of the longest time spans and resulted in one of the largest reductions among the contribution analysis pilot cities. Emissions related to growth in population and employment were outpaced by a less carbon-intensive electric fuel mix and reduced waste per capita.

Largest Contributors to Emissions Growth

- Population growth
- Increased commercial sector size

Largest Contributors to Emissions Decline

- Less carbon-intensive electric fuel mix
- Reduced waste per capita



Shoreline, Washington

The City of Shoreline is committed to reducing emissions by 50% by 2030 and 80% by 2050. Shoreline actively participates in the King County-Cities Climate Collaboration (K4C) to protect the climate throughout King County. The city has completed several projects to lead by example, creating an environmentally preferable purchasing policy and achieving LEED Gold status in the construction of City Hall in 2009.

What is Driving the Trends

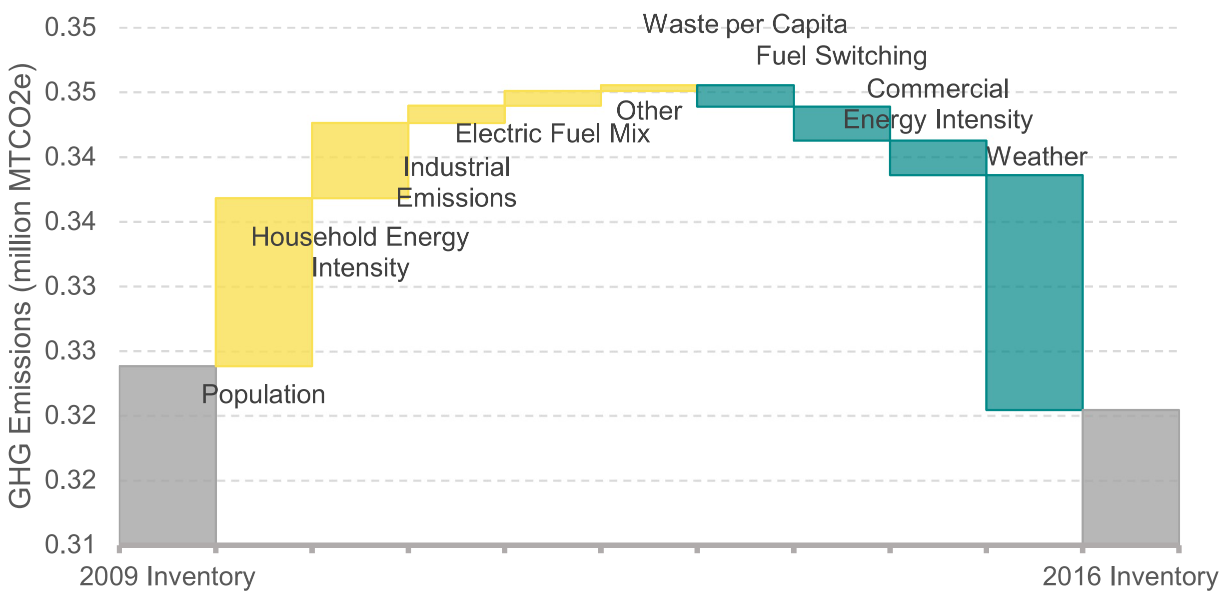
Shoreline ran the contribution analysis on the city's GHG emission trends for 2009-2016. Although emissions increased from population growth and residential natural gas usage per household, overall emissions reductions were achieved by more households switching to electric heat and reduced commercial energy intensity. A warmer winter in 2016 had the most significant impact toward reducing emissions.

Largest Contributors to Emissions Growth

- Population growth
- Increased household energy intensity

Largest Contributors to Emissions Decline

- Warmer winter and cooler summer
- Reduced commercial energy intensity



Combined Pilot Community Results

Combined Results

Figures 2, 3, and 4 below illustrate the relative contributions of various factors to the average annual percent change in GHG emissions within sectors and energy types. Displaying the results in average annual percentage terms helps to normalize for the large size disparities between communities and differences in time periods. Each line in the charts relates to a single community connecting the impacts made by major analyzed factors. A key aspect of the contribution analysis methodology is that the calculated impact of each factor considers all other factors. As a result, the factor order does not change the numerical values, and the sum of individual factor impacts yields the overall net impact.

Commercial Sector

In the commercial sector on a percentage basis, weather is clearly a much stronger factor on stationary combustion of fuels, such as natural gas, than on electricity. This is unsurprising, given that stationary combustion is used primarily for space conditioning; however, electricity use is generally a much larger portion of an overall inventory and is used for both heating and cooling. Not visible Figure 2 below is that in absolute terms of the change in total tons of CO_2e, the high percentage change in stationary combustion does equate to overall larger differences in emissions than the impact of weather on electricity usage, despite size of the electric load of a typical community.

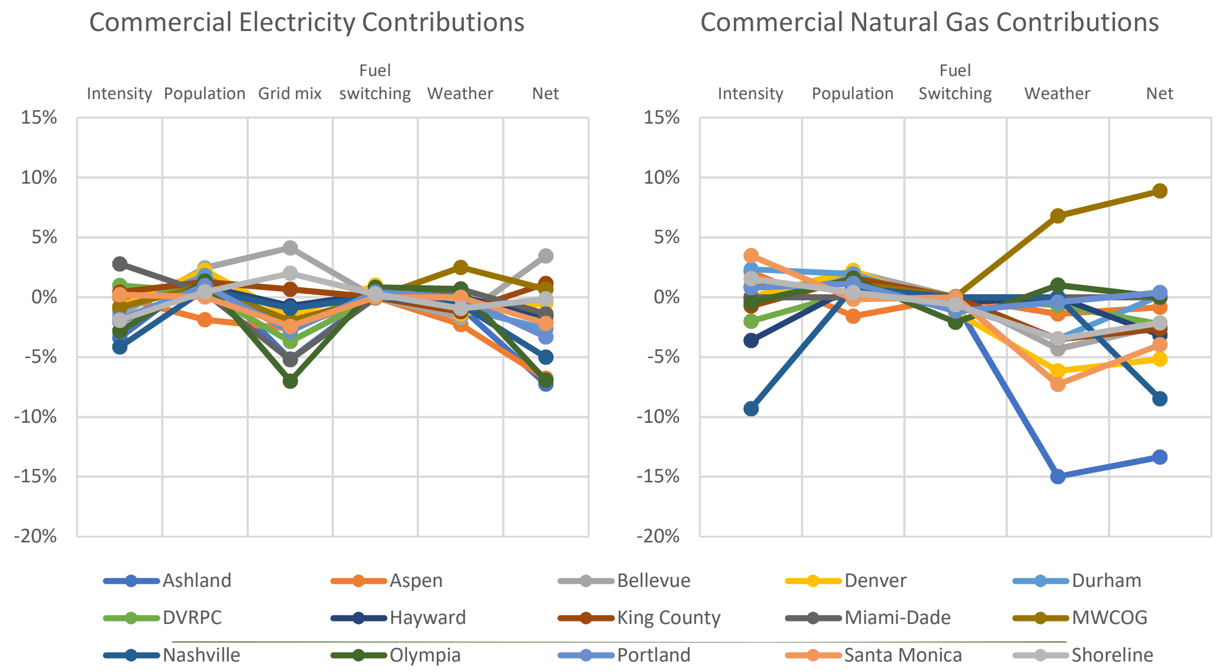


Figure 2. Commercial sector attribution analysis for electricity use (left) and direct combustion use (right). Points represent average annual changes in electricity and direct combustion related GHG emissions. Summation over all factors yields the net average annual percent change.

While individual years may be hotter or cooler, the overall trend observed in warmer winters now appears to be driving net reductions in energy use, even as warmer summers increase electricity use. Note several of the pilot communities are in relatively cool areas, and this trend may not hold across all regions of the country.

Also unsurprising is the size of the impact of changes to the electric grid mix. It is the dominant factor for many of the communities in the pilot for determining the change in emissions from the sector, but is not always in a downward trajectory.

Growth in the commercial sector is positive in most cases, which drives some amount of increase; however, most of the time, growth is more than offset by improvements to the overall efficiency of the sector and carbon intensity of the electric grid. This is a good signal of increasing efficiency of the commercial sectors of these communities.

Residential Sector

In the residential sector, very similar trends are visible across weather, growth, and improvements in energy efficiency. Per capita energy use does not appear to be increasing in some communities, which must be addressed if net trends in emissions are to decrease at the pace necessary to meet global reduction targets.

Transportation

Fewer factors can be analyzed in the transportation sector. In this case, changes to on-road gasoline use was attributed to changes in fuel economy used in each inventory, population growth, and the key indicator of vehicle miles traveled per capita. Generally

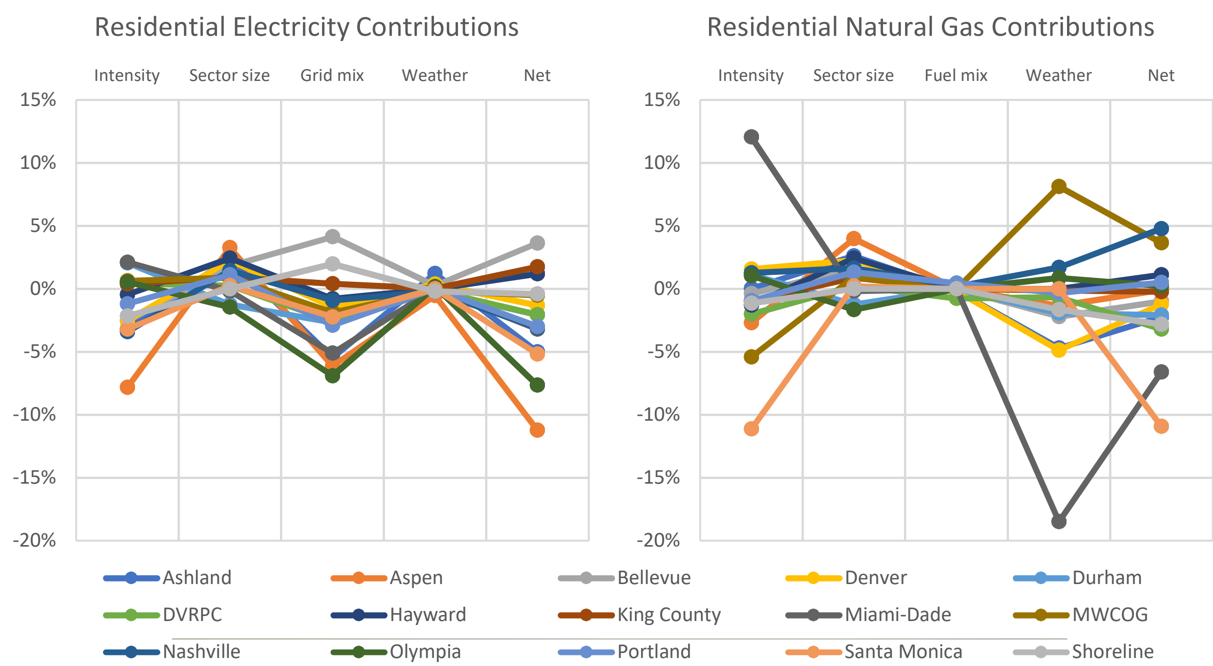


Figure 3. Residential sector attribution analysis for electricity use (left) and direct combustion use (right). Points represent average annual changes in electricity and direct combustion related GHG emissions. Summation over all factors yields the net average annual percent change.

good trends are visible among this set of communities where reduced vehicle miles traveled per capita is outweighing the influence of population growth; however, it is important to consider that the true impact of population growth on transportation emissions occurs at the regional scale and may not be fully captured among these pilot communities.

This analysis indicates overall progress is being made when external drivers of change have been accounted for. What is also clear from this analysis is that each city faces a unique set of factors working to determine outcomes related to GHG reduction, which should be considered when prescribing the right mix of mitigation strategies to address those factors specifically.

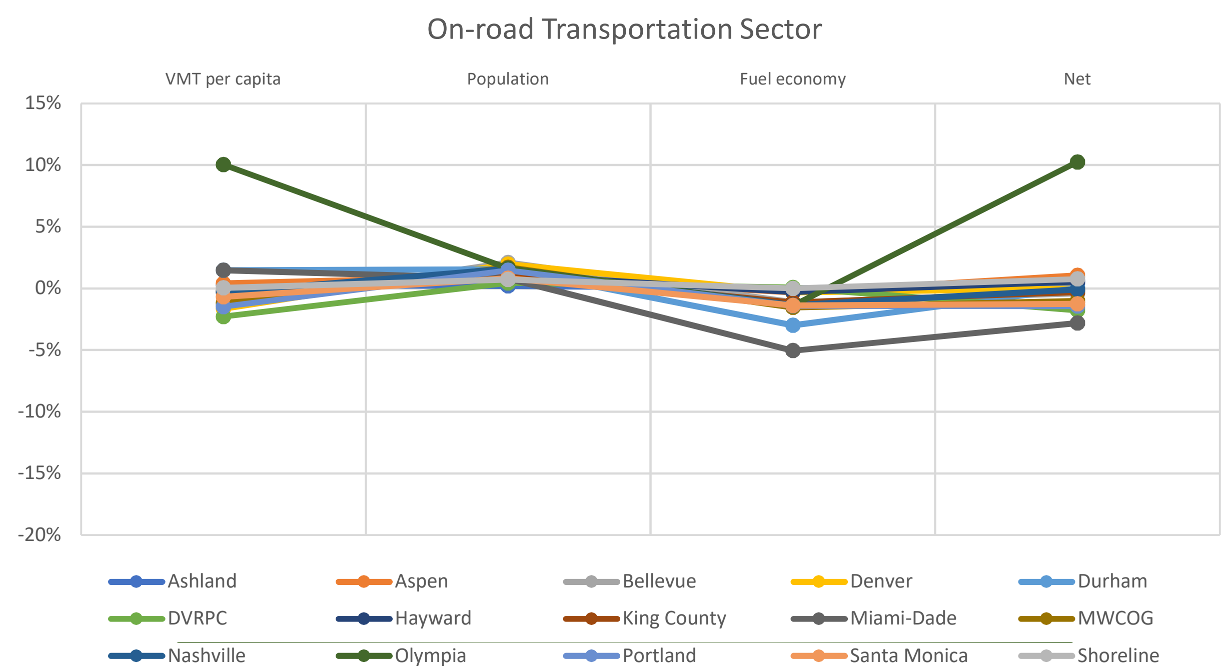


Figure 4. On-road transportation sector attribution analysis. Points represent average annual changes in GHG emissions. Summation over all factors yields the net average annual percent change.

Impact on the State of Practice

In less than six months following the initial release, the toolkit was downloaded 234 times. Basic demographics were collected voluntarily for each download, indicating the wide level of interest from a variety of practitioners spanning the United States and beyond. Local government staff makes up the largest segment of downloaders representing users across 40 states. These are followed by private firms, non-governmental organizations (NGOs), and universities. A small number of regional, state, and federal agencies have also shown interest. Most interesting is that 35 individuals outside of the United States from all different sectors have also downloaded the resource.

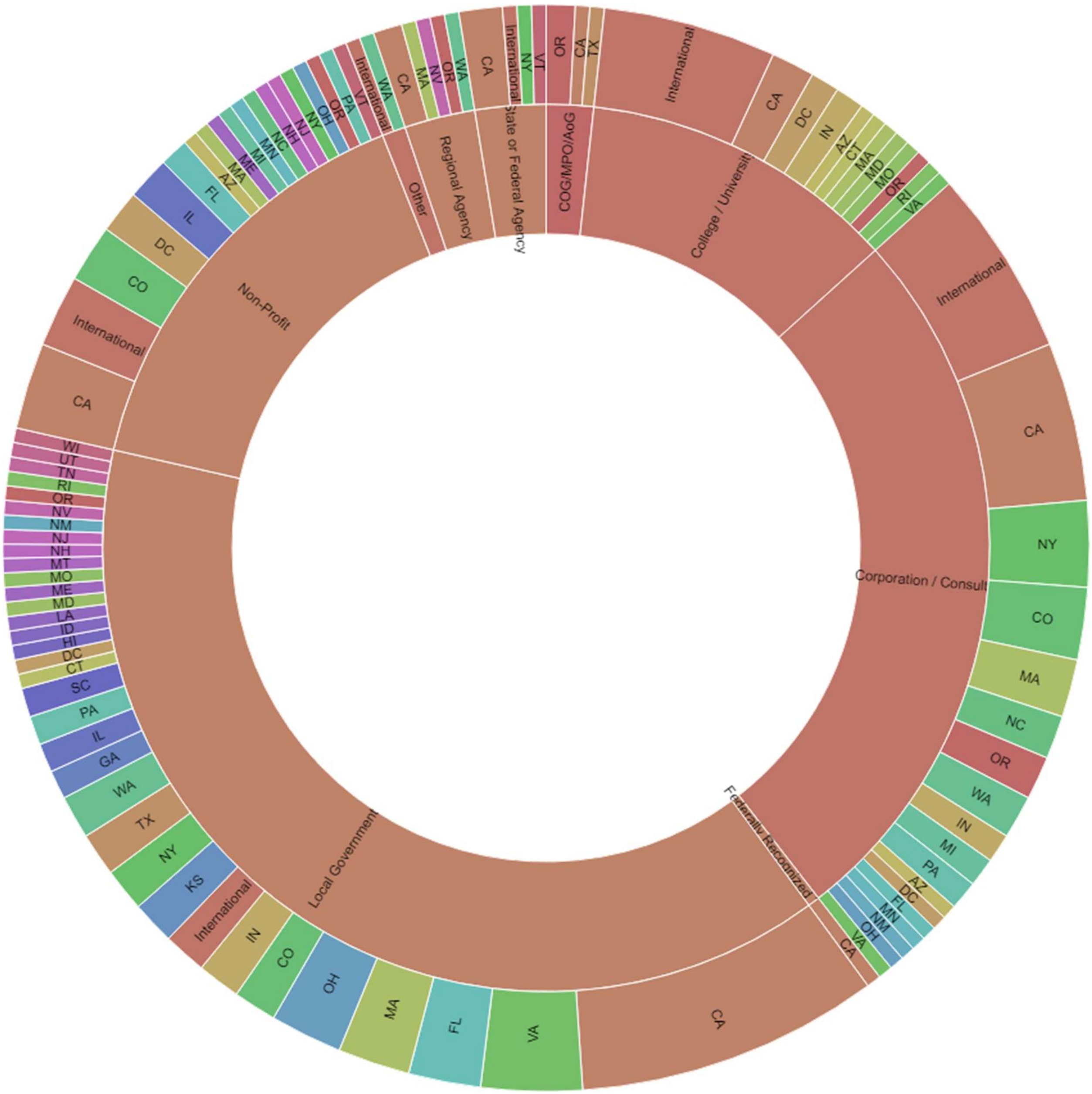


Figure 5. Breakdown of contribution toolkit downloads by state and by type of organization

The level of interest from such a diverse group is surprising but speaks to the widespread interest in understanding the kind of dynamics the toolkit addresses.

Already there are anecdotal instances of contribution analyses included in the scope of services requested in public bidding processes for local government contracts and instances of the framework being applied to other subjects, such as in the analysis of the generation mix portfolio of community-choice aggregation electricity suppliers. With this level of interest immediately after release, a contribution analysis may possibly become an expected component of any multi-year GHG performance report.

Future Applications and Conclusions

Future Applications

This project applied the approach of contribution analysis to the study of community-scale GHG performance evaluation, applying techniques including LMDI, community-wide degree-day normalization, and simple indicator-based decomposition to account for as many factors as possible in a toolkit that is easily used by practitioners. The product reflects several data constraints that policymakers concerned with community-scale energy consumption and emissions face today.

Utility data is often fairly aggregate and not explicitly connected to end uses but rather broad customer classes; transportation data is often modeled instead of measured. Data on a range of factors likely to be influencing the results are unable to be combined with locally developed measures of activity levels, due to disparities in the scale at which each type of data is generated. The good news is that the field of practice is always on the lookout for improved datasets and generating more information locally. It is highly likely that some of these limitations will be overcome in the near future. Some examples of near-term variations on the Contribution Analysis could include:

More Granular Energy-Use Data Matched to Building Typologies

Local governments' knowledge of the quantity and performance level of building space in their communities is growing with the digitization of tax assessor and planning information. While obtaining energy data at similar resolution from utilities will remain challenging, other avenues are showing some promise. Building disclosure programs offer one route for more publicly available performance data. These programs are typically focused on a subset of buildings in a community, but the contribution analysis technique could be applied to just those buildings to better understand their performance in relation to external drivers.

If traditional evaluation methods are used to assess buildings under a disclosure ordinance, results of that subset could also be applied in a community-wide contribution analysis, providing additional information about how buildings under a disclosure program are performing against the community-wide average.

Energy Performance Benchmarks for Local Industries

The weather variation component of the analysis performed in this project required first developing a regression model of energy consumption as related to variation in heating- and cooling-degree days. A similar approach could be taken with other types of models developed for a community that can relate fluctuation in energy use to another external driver. One example is a model combining local energy benchmarks of different industries that could be tied to data on economic activity for the two inventory years. Attempts made through this project to use existing datasets from the EIA, such as the

Manufacturing Energy Consumption Survey (MECS)[10] and Commercial Building Energy Consumption Survey (CBECS)[11], are challenging to downscale to a resolution that would match the boundaries of a community-scale inventory. With some guidance, cities could develop appropriate industry benchmarks for their local businesses through voluntary disclosure mechanisms. Ideally, the regression analysis would incorporate both degree day and economic drivers simultaneously, which should improve the overall strength of the model and the confidence of each component.

Out of Boundary Analyses

In addition, there are several different variations on the community-scale GHG inventory, such as a demand-centered hybrid life cycle approach, consumption-based inventories, or simply the inclusion of indirect emissions immediately upstream or downstream of a community for energy and goods consumed. These types of inventories are largely dependent on published emissions intensities of the activities outside of the community boundary, for example, in the extraction, refinement, and distribution phases of fuels. The contribution analysis approach is well suited for disaggregating the effects of intensities and quantities of different fuel types. Communities in states that have low-carbon fuel standards in place may be able to use these techniques for examining how shifts in the production pathways of fuels can maximize life cycle emissions reductions.

GHG Reduction Planning

The contribution analysis technique could potentially be applied to exploring the interplay between varying emissions rates and levels of the related emissions-generating activities in a climate action planning exercise. One question that is commonly asked in that activity is how to evaluate the potential of both clean energy and efficiency simultaneously from an ex-ante perspective. Hypothetical GHG inventories of a future with actions applied could be constructed and the results decomposed. A waterfall-style visualization may be a useful alternative or compliment to the typical wedge diagram commonly used today.

Evaluation of Projected Climate Impacts

A side product of the community-scale degree-day regression analysis is parameter estimates on the expected energy response by weather-driven thermal demand for heating and cooling. Sources of data are now readily available for heating- and cooling-degree days from global climate projection models, downscaled to the local level. The parameter estimates from the regression analysis could be combined to look at possible

[10] U.S. Energy Information Administration. “Manufacturing Energy Consumption Survey (MECS).” Last modified September 6, 2018. https://www.eia.gov/consumption/manufacturing/.
[11] U.S. Energy Information Administration. “Commercial Building Energy Consumption Survey (CBECS).” Last modified May 29, 2019. https://www.eia.gov/consumption/commercial/.

changes in energy demand for space conditioning across the community and the related impacts on GHGs, as well as household and business energy expenditures. Such information would also be valuable in targeting appropriate efficiency measures to mitigate projected outcomes.

Conclusions

In the short time since its release, this project has made a noticeable impact on the way local governments and related agencies assess and interpret their progress on managing energy and other GHG generating activities. This is even though the toolkit and analysis procedures were built around the use of fairly coarse scale datasets that communities often work with. The ability to track performance in a meaningful way is enabled by the generation of high-quality local data about emissions generating activities themselves, as well as several local conditions and contextual factors. Moving forward, communities that can fully describe their built environment, transportation, and waste management systems with data will be best able to meaningfully track trends and formulate data-driven policy to create more sustainable communities.

This project team hopes the work performed here will be continued by curious minds and decision makers who demand more of the data they collect and use to manage communities. That is what will lead to new insights and greater understanding of the policy choices ahead as communities strive to eliminate their carbon emissions.

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